Pentaquark Search *
at
HERA-B

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for the HERA-B collaboration

* simultaneous study of

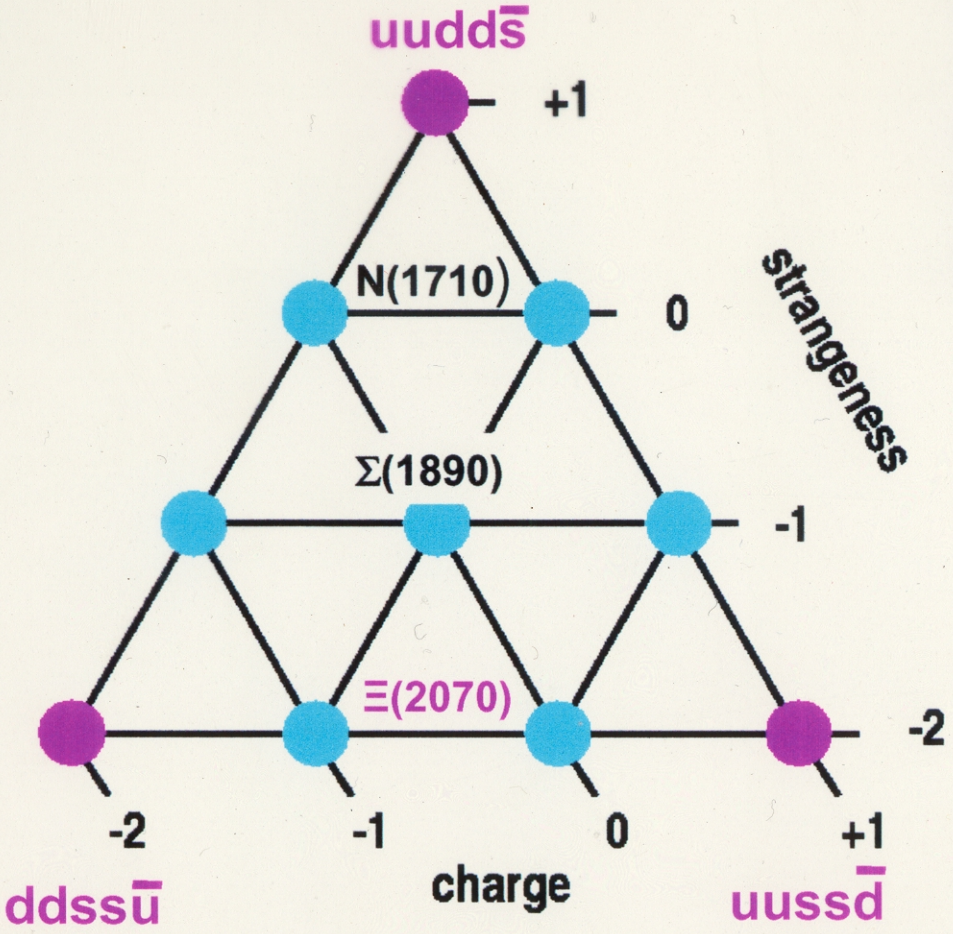
$\Theta^+ \to p K^0_S$

$\Xi^{--} \to \Xi^- \pi^-$ (+ c.c.)

using high statistics data sample

The Prediction

$\Theta^+(1530) \rightarrow nK^+$ or pK^0



$\Xi^{--}_{3/2} \rightarrow \Xi^-\pi^-$ or Σ^-K^- $\quad\quad$ $\Xi^{+}_{3/2} \rightarrow \Xi^0\pi^+$ or Σ^+K^0

The anti-decuplet proposed by Diakonov, Petrov & Polyakov (Z.Phys.A359 (1997) 305) with the three exotic baryons at the corners - requiring the indicated five valence quarks - and their decay modes.

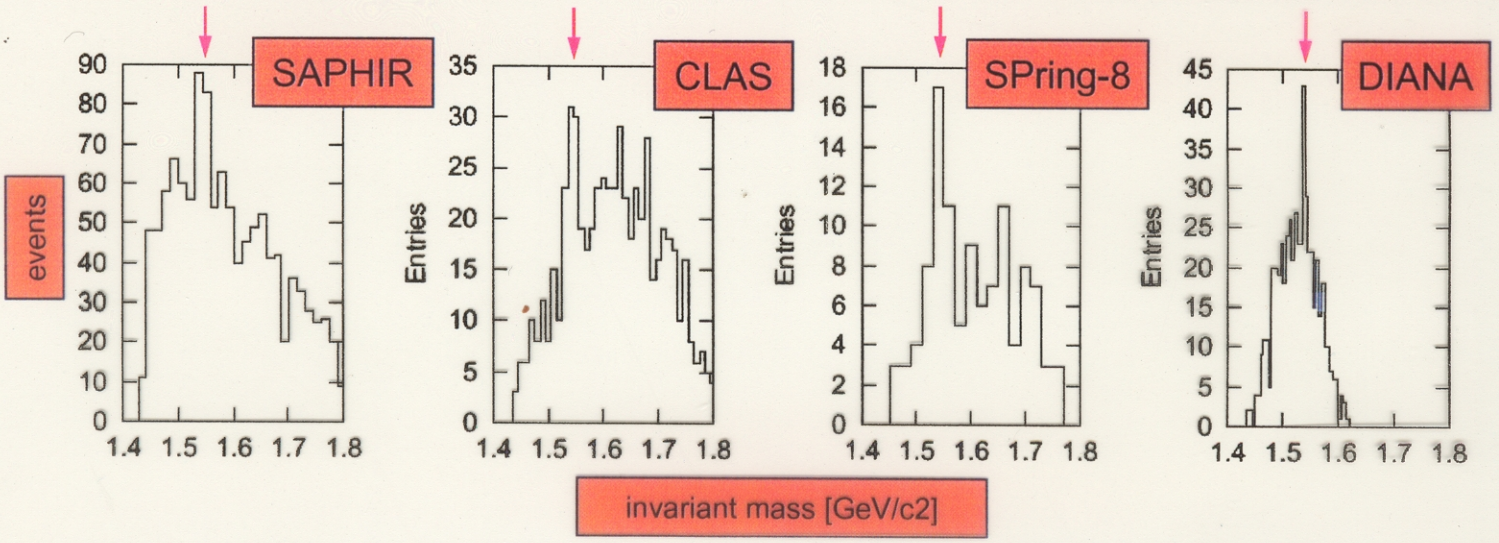
Masses in MeV are given in parentheses.

Most exciting for experimental investigations is the prediction of a width of less than 15 MeV for the $\Theta^+(1530)$ state.

Recent Experimental Evidence

Θ^+: Evidence for a new exotic state at ~1540 MeV in the pK^0 and nK^+ channels with a width of less than 25 MeV has been reported from experiments using incident beams of real and quasi-real photons, kaons, and (anti-)neutrinos. Best constraints on its width come from a re-analysis of K+d and K+p scattering indicating that the width should be less than 'a few MeV'.

Reaction	E(beam)/GeV	Mass/MeV	Experiment / Reference
$C(\gamma,K^+K^-)X$	1.5 – 2.4	1540±10	SPring8 / PRL91 (2003) 012002.
$d(\gamma,K^+K^-p)[n]$	<3.1	1542±5	CLAS / hep-ex/0307018.
$p(\gamma,K^+K^0)[n]$	1.74 - 2.6	1540±4±2	SAPHIR / PL572 (2003) 127.
$Xe(K^+,K^0p)Xe'$	0.5	1539±2	DIANA / Yad.Fiz.66 (2003) 1763.
$p,d,Ne(\nu,K^0p)X$	37-137	1533±5	ITEP / hep-ex/0309042.
$p(\gamma,K^+K^-\pi^+)[n]$	3 - 5.47	1550±10	CLAS / hep/ex033046.
$d(e,K^0p)X$	27.6	1528±2.6±2.1	HERMES / hep/ex0312044.
$p(p,\Xi^-\pi^-)X$	158	1862±2	NA49 / hep/ex0310014.

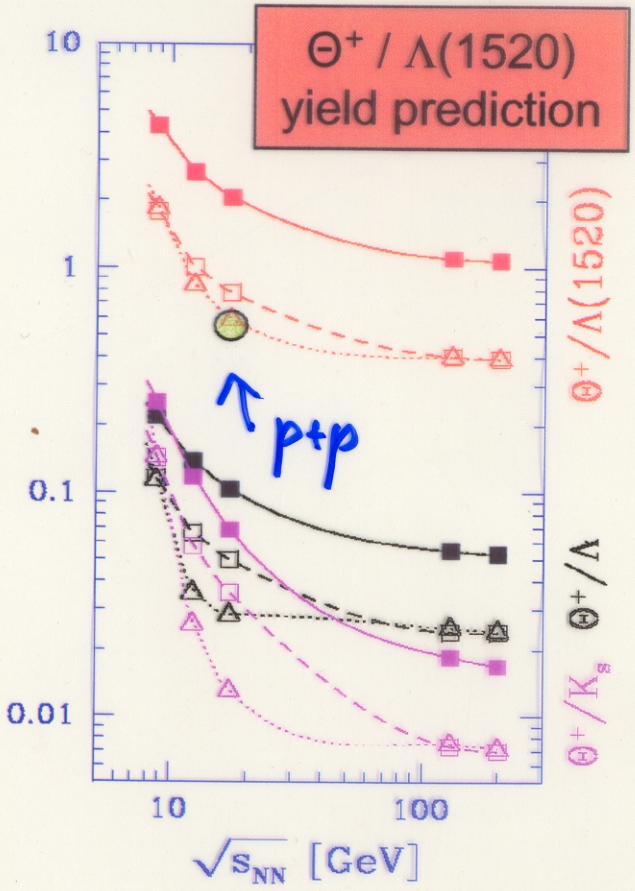


Ξ^{--}: Evidence for a second new exotic state at ~1862 MeV with a width of less than 18 MeV in the $\Xi^-\pi^-$ channel has been reported by the NA49 collaboration in p-p collisions. At the same mass, a peak is seen also in the $\Xi^-\pi^+$ channel (hep-ex/0310014). These peaks are candidates for the exotic Ξ^{--}(I=3/2) baryon and the Ξ^0 member of this isospin quartet.

Open Topics & Possible HERA-B Contributions

- Confirmation of pentaquark candidate signals beyond any doubt. → HERA-B search profits from huge minimum bias sample; with 10 times the statistics, scrutiny of NA49 result seems straightforward.
- Measurement of spin, parity, width, and cross section → HERA-B is able to study at mid-rapidity pentaquark signals simultaneously in various final states with a mass resolution of a few MeV.
- Understand production mechanism. → HERA-B can provide relative particle yields at mid-rapidity.

Relative yields of Θ^+ to $\Lambda(1520)$ production have been predicted for heavy ion collisions assuming statistical hadronization (Letessier et al. hep- ph/0310188 - see figure!). Becattini et al. (hep-ph/0310049) obtain similar results and predict in addition the $\Theta^+/\Lambda(1520)$ yield for p+p collisions at $\sqrt{s}$=17.2 GeV (**see green dot!**).

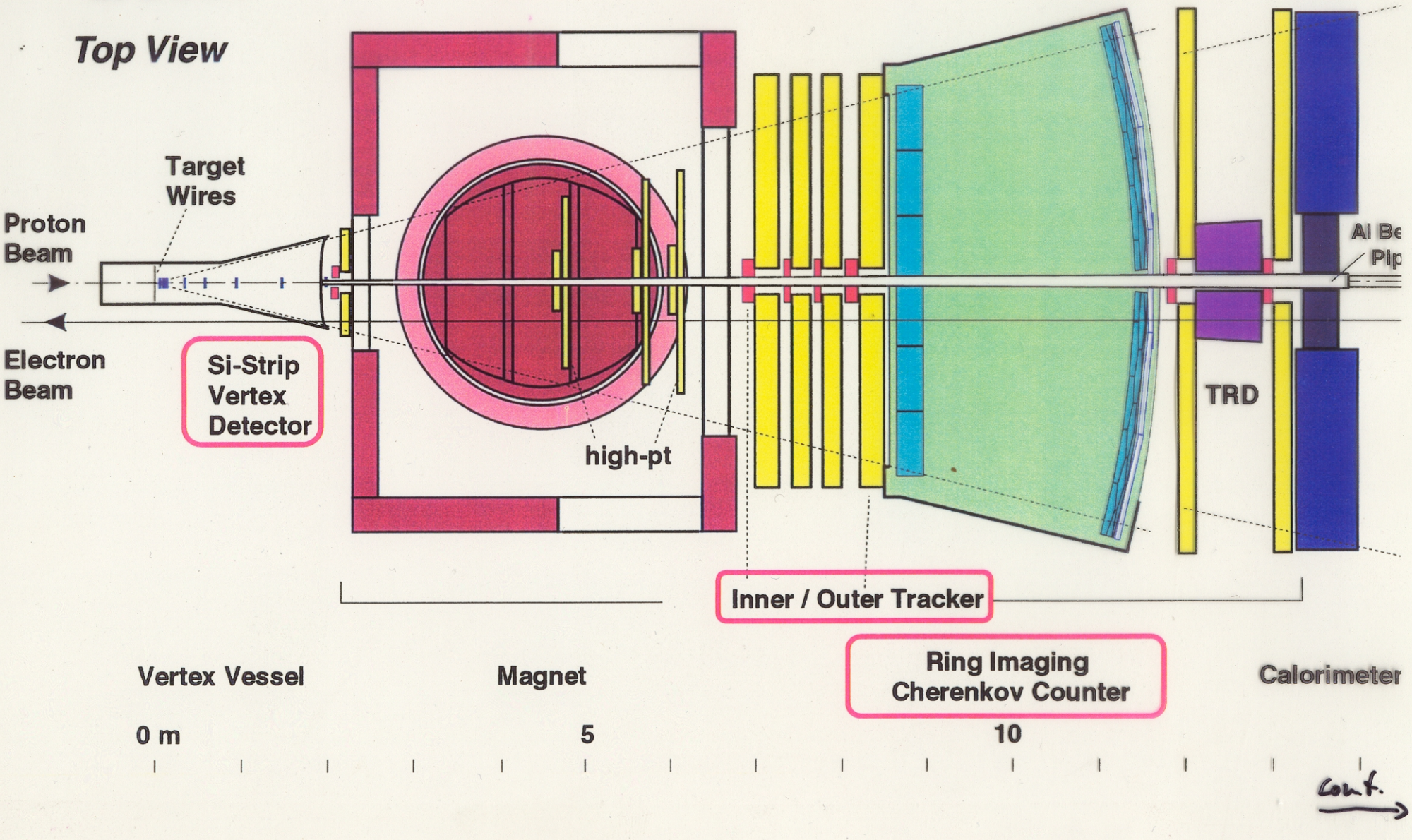


$p + A \; @ \sqrt{s} \sim 42\,GeV$

A: C, Ti, W

large min. bias sample (> 200 M)

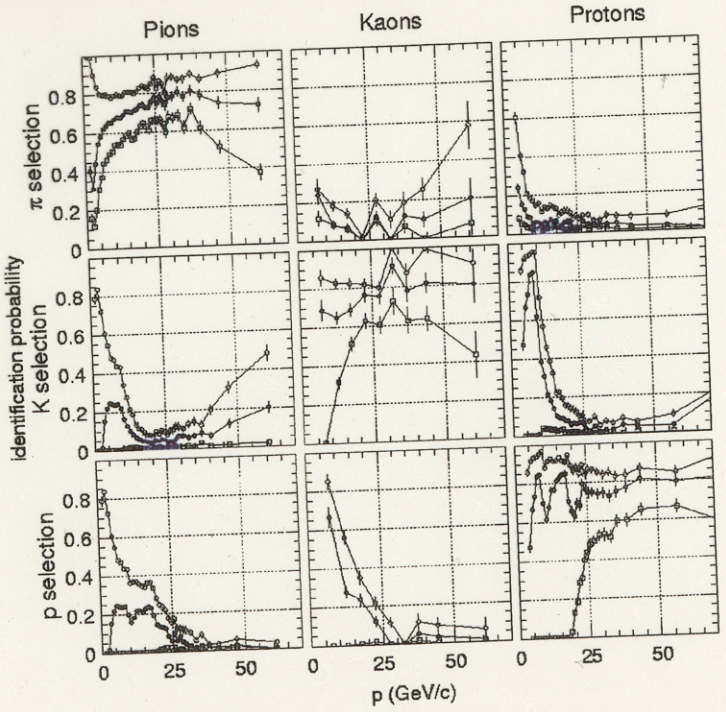
The HERA-B Experiment at DESY



cont.

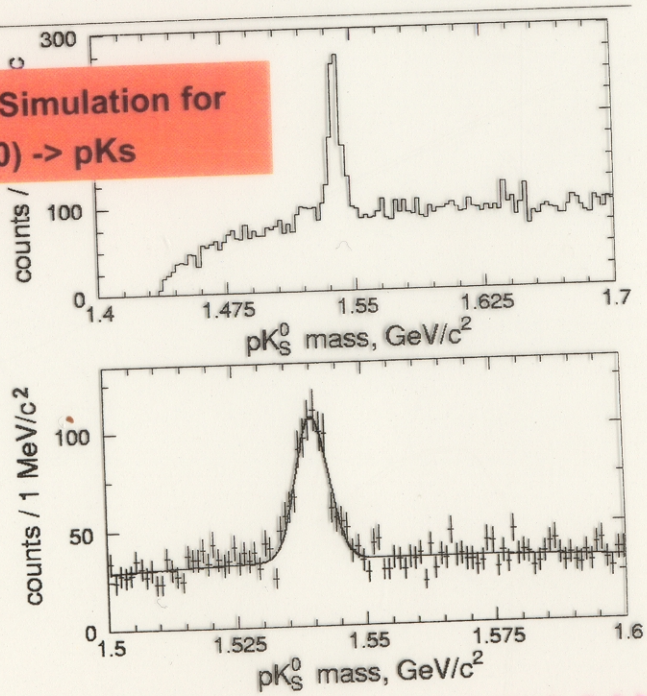
The HERA-B Forward Spectrometer

- Interaction of 920 GeV/c protons with C, Ti and W target wires at proton storage ring HERA.
- Large aperture (15 – 160 (v) resp. 250 (h) mrad) and high resolution spectrometer.
- Good particle identification (e, μ, π, K, p) by RICH and muon filter,
- Subdetectors used in present study: silicon vertex detector, tracker, RICH
- 1 kHz data acquisition rate for minimum bias sample.
- Excellent proton identification for momenta from 20 to 55 GeV/c.



RICH particle identification (PID) probabilities

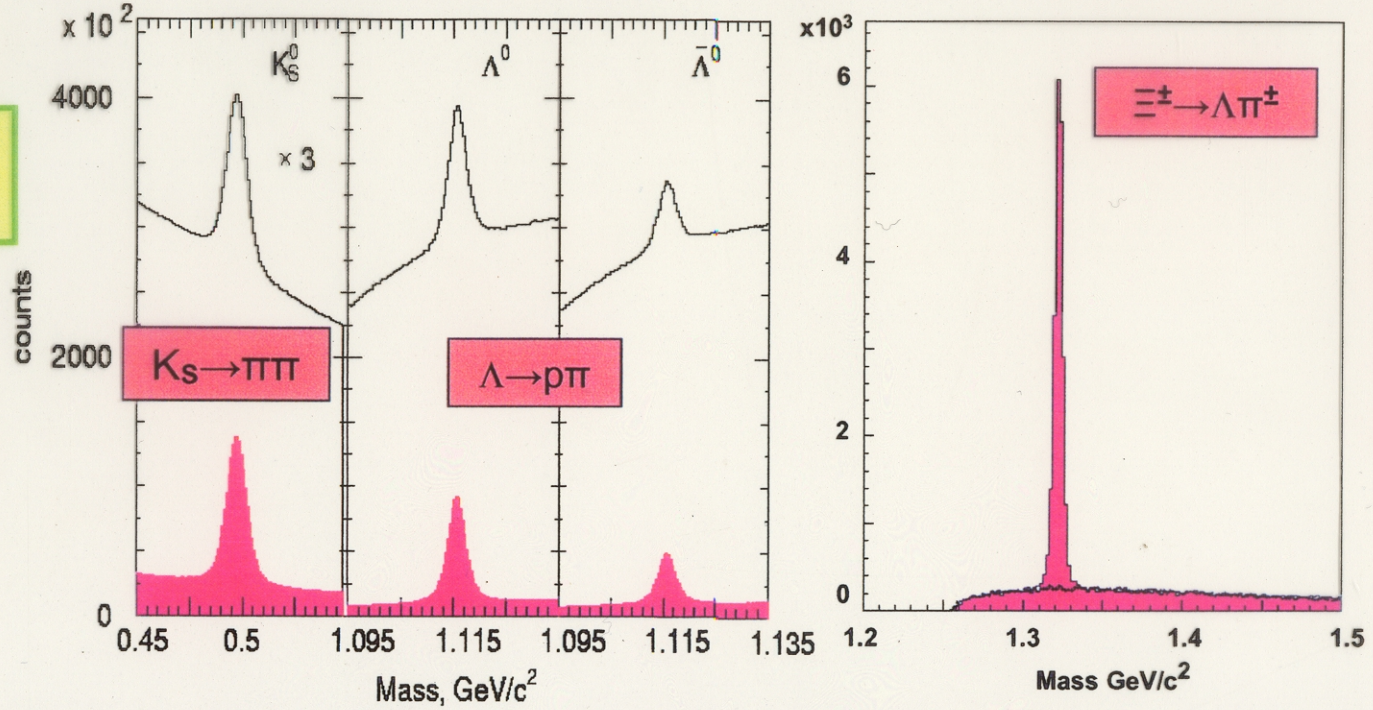
Monte Carlo Simulation for Θ⁺(1530) -> pKs



Mass resolution is σ = 3.2±0.2 MeV

The Data Sample

A sample of more than 160 millions of p + A minimum bias events taken in 2002/03 on Carbon (76M), Titanium (16M) and Tungsten (72M) targets was used for this analysis.



Statistics	Resolution
K_S $3.4 \cdot 10^6$	4.9 MeV
Λ $9.4 \cdot 10^5$	1.8 MeV
$\bar{\Lambda}$ $4.5 \cdot 10^5$	dto
Ξ^- $1.1 \cdot 10^4$	2.6 MeV
Ξ^+ $7.7 \cdot 10^3$	dto

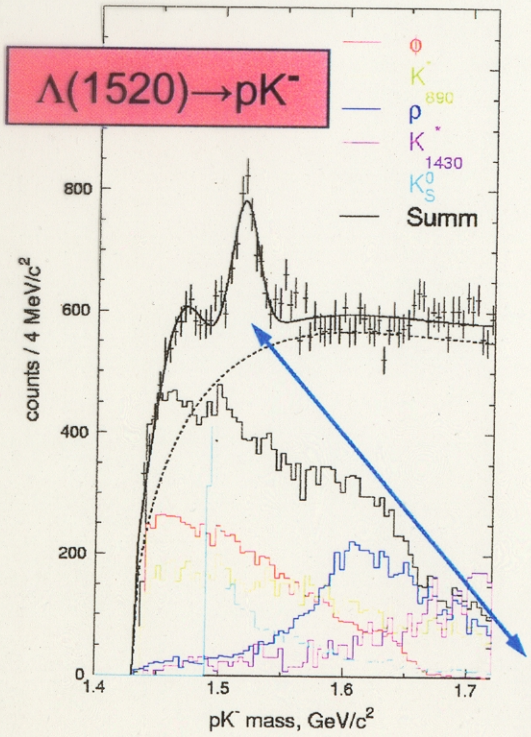
Selection criteria for K_S and Λ (distance of closest approach < 0.7mm, and $c\tau \cdot pt > 0.05$ cm·GeV/c) remove 90% of background and keep 95% of signal. – Ξ signals are selected by requesting that none of the decay products points to the primary vertex while the Ξ itself must point to the primary vertex. For more details see adjacent poster [Strange 9] by T. Zivko!

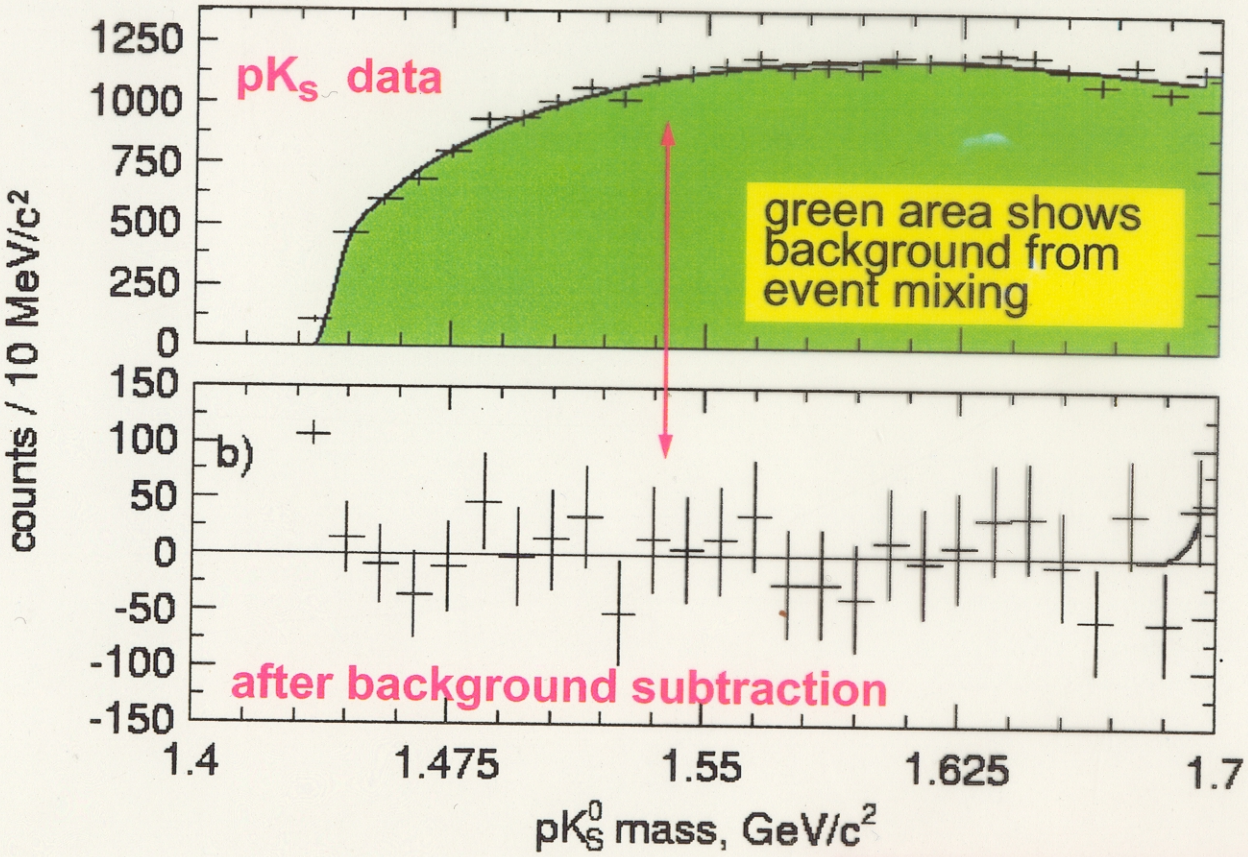
Pentaquark search in pK_s final state in p+C collisions

Strategy: exploit huge MinBias statistics on Ks and apply strong RICH PID on proton.

Applied cuts:

- detached K_s vertex
- Λ contamination removed
- primary vertex request
- proton likelihood > 0.95

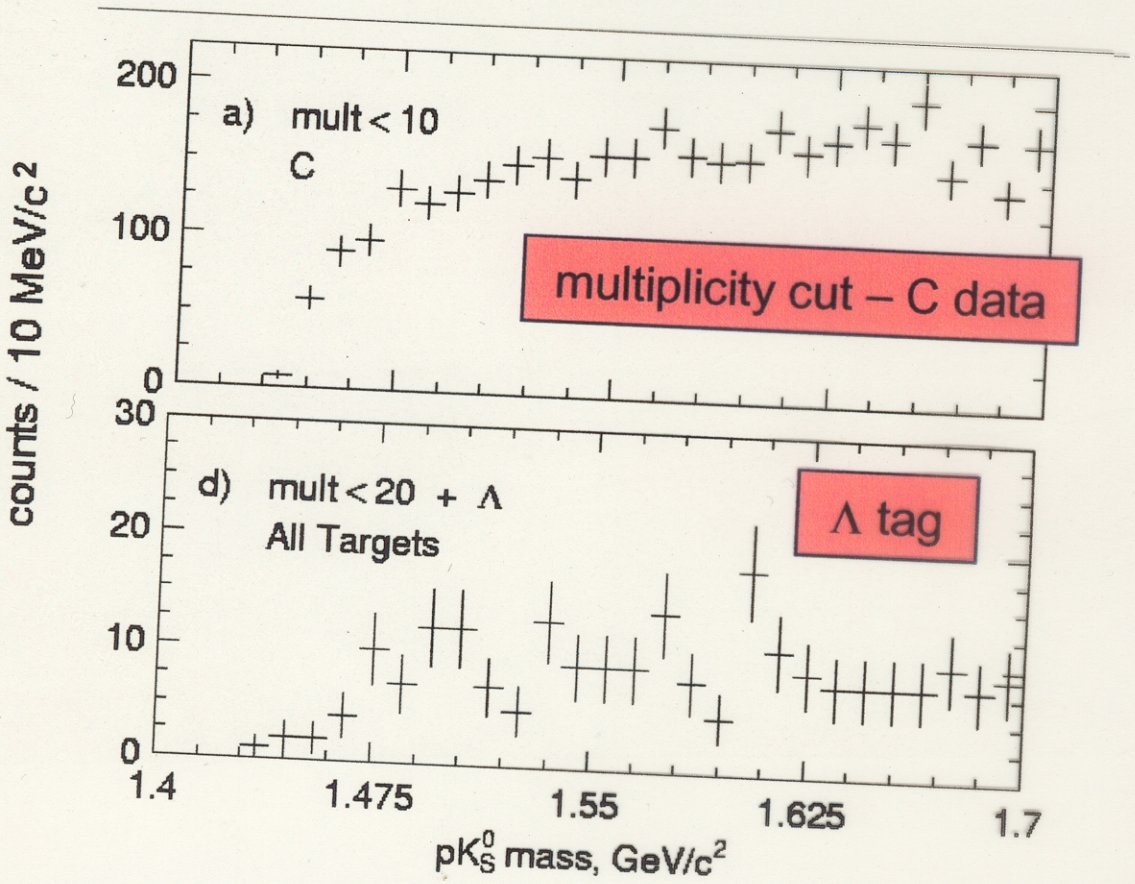




no narrow signal visible!

Performance of PID checked on reconstruction of $\Lambda(1520)\rightarrow pK^-$
Reflections of indicated resonances included in background shape.

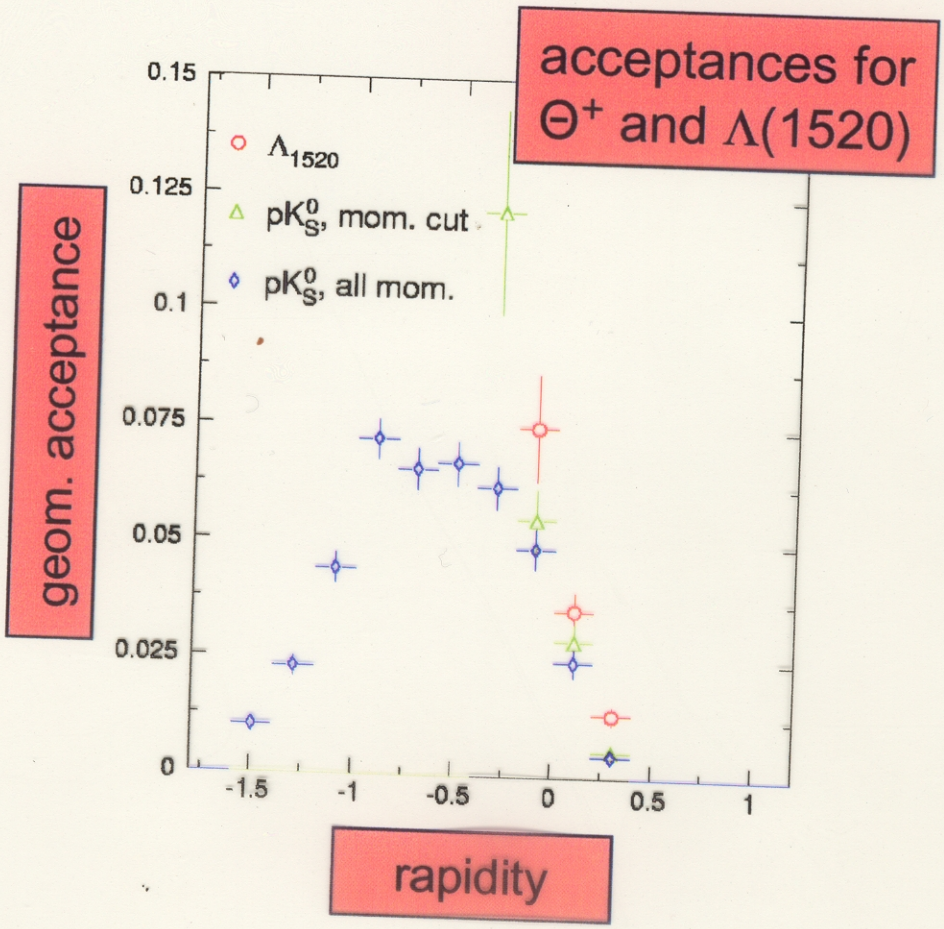
Many alternative search strategies:

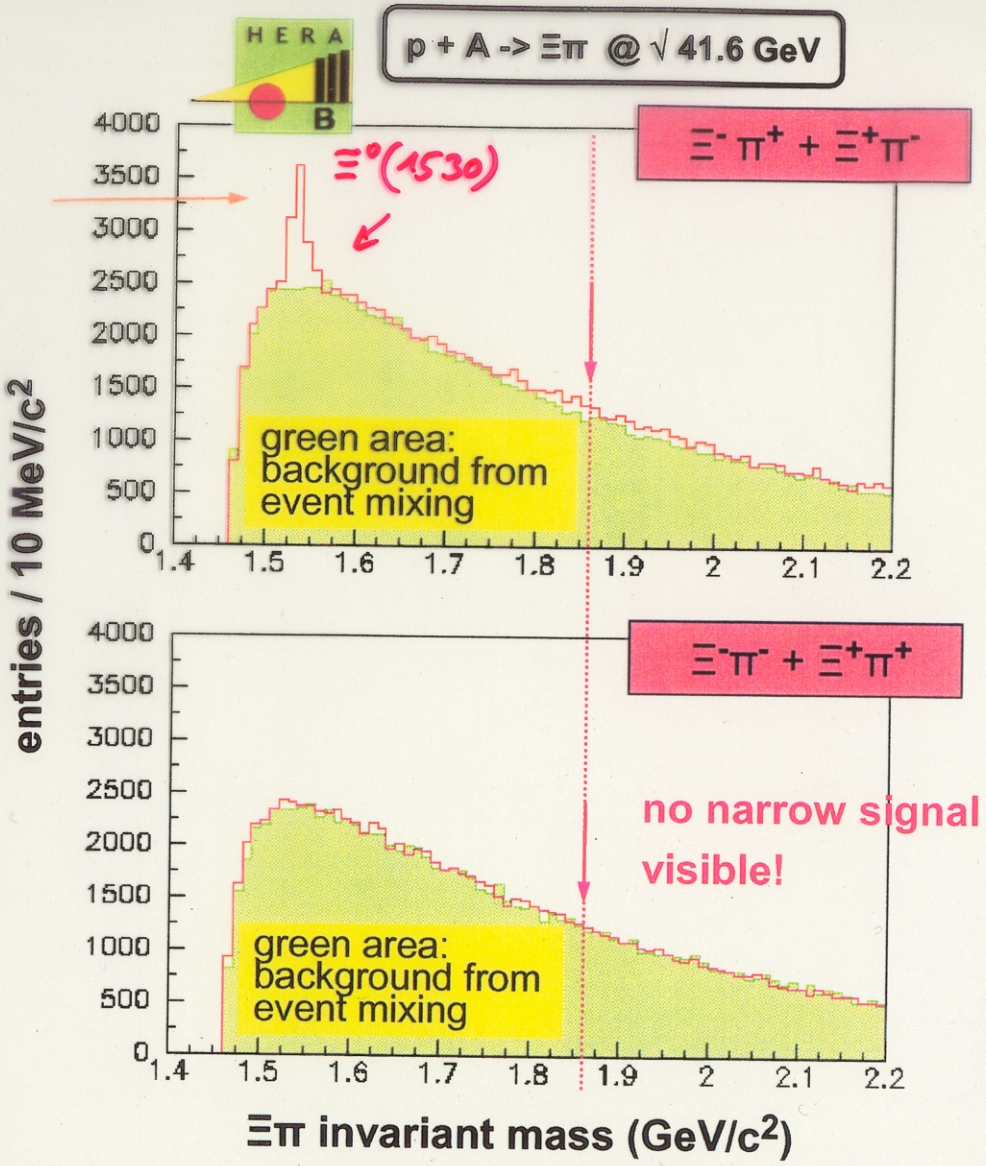


- track multiplicity cuts on C, Ti and W data
- Λ or Σ tag requirement with & w/o multiplicity cut
- detached vertex request
- relaxation of proton momentum cut & PID

Quantitative Results of Θ^+ Search

- At midrapidity, the sensitivity in BR · dσ/dx is better than 5 μbarn/nucleon for a narrow state. An upper limit for the cross section will be provided.
- The geometrical acceptance for pK_S , i.e. $\Theta^+(1540)$, and $\Lambda(1520)$ is very similar at mid-rapidity, see figure! A preliminary value for the upper limit of the relative yield $\Theta^+/\Lambda(1520)$ at mid-rapidity is $2 \cdot 10^{-3}$ at 95% CL.
- This relative Θ^+/Λ yield is significantly lower than the statistical hadronization model prediction of ~0.6 for p-p collisions at $\sqrt{s}$~17 GeV (Becattini etal.hep-ph/0310049).





HERA-B Results:

- In $\Xi^- \pi^+$ channel, prominent $\Xi^0(1530)$ signal and possible weak evidence for known higher Ξ^* resonances.
- In $\Xi^- \pi^-$ channel, **no evidence** for narrow signal between 1.8 and 1.9 GeV. Sensitivity for a narrow $\Xi^{--}(1862)$ signal at mid-rapidity is in the order of $Br \cdot d\sigma/dx \sim 10$ μbarn/nucleon.
- Preliminary values for the upper limits of the relative production yields $\Xi^{--}(1862) / \Xi^0(1530)$ resp. $\Xi^{++}(1862) / \Xi^0(1530)$ are 0.04 and 0.055.
- Sensitivity reached to test predictions of Letessier et al., hep- ph/0310188.

NB: In Σ^-+A collisions, WA89 (EPJ C5 (1998) 621) sees in the $\Xi^- \pi^+$ channel the $\Xi^0(1530)$ (~63k decays) and the $\Xi^0(1690)$ states – but no statistically significant signal at 1862 MeV..

PQ search in $\Xi^-\pi^-$ and $\Xi^-\pi^+$ resp. c.c. final states

Conclusions on HERA-B Pentaquark Search

- Exploited large statistics of min. bias sample and high detector resolution.
- Strong signals from $\Lambda(1520) \rightarrow pK^-$ and $\Xi^0(1530) \rightarrow \Xi^- \pi^+$ reconstructed.
- **No evidence** for narrow pentaquark signals in pK_S or in $\Xi^- \pi^-$ channels.
- Sensitivity of $Br \cdot d\sigma/dx$ to a $\Theta^+(1540)$ signal is better than 5 μbarn/nucleon.
- At mid-rapidity, the relative yield ratio $\Theta^+(1540) / \Lambda(1520)$ is < 0.002.
- At mid-rapidity, the relative yield ratio $\Xi^{--}(1862) / \Xi^0(1530)$ is < 0.04.
- More systematic studies and cross section evaluation in progress.
- If existent, pentaquarks seem to exhibit also exotic production mechanisms.